(A000 6869)

19 Feb 75

To: Structural Design Section
Design Personnel

Attached is an explanation of the effective width of skinplate to be used in the design of vertical rib members for gates. This explanation was presented by Don Dressler, LMVD.

What can be concluded from this explanation is that we can use an effective flange width of 42 times the skinplate thickness (for Fy = 36 ksi) in the design of vertical ribs with a continuous skin plate acting as the flange. We have been using an effective flange width of 32 x the skinplate thickness for our gate designs.

The 42t requirement is derived from the expression $1.5\sqrt{\frac{E}{F_y}}\,t$ presented in EM 1110-2-2702. 32t was derived from the requirements of AISC Section 1.9.1. The EM expression is for members with continuous flanges (skin plates) whereas the AISC requirement has application for flanges with free ends. (W Flanges, Plate Girders)

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DCO

References:

1. Structural Steel Design by L.S. Beedle, et. al, Ronald Press, 1964, pp. 208, 531-538.

2. Steel Structures: Design & Behavior by C G Salmon & J. E. Johnson, Intext, 1972, pp. 300-303, 294, 324-328.

3. Manual Of Steel Construction by AISC, 7th Edition, 1970, pp. 5-17, 5-18, 5-124, 5-125, 5-25, 5-26, 5-140, 5-141, 5-142, 5-115, 5-116, 5-117, 5-60, 5-61, 5-161, 5-165.

ie W shapes etc

Local Buckling Provisions For Flanges:

a) Attaining The Yield Moment (M_y):

$$\lambda = 0.7 = \sqrt{\frac{F_y}{F_{cr}}} \quad \text{(eqn 17.21)} \qquad \frac{b}{t} \le \frac{3600\sqrt{k'}}{\sqrt{F_y'}} \quad \text{(eqn ...)}$$

$k = 0.7$ (para 17.4,2,2) $\qquad \boxed{\frac{b}{t} \le \frac{3012}{\sqrt{F_y'}}}$ (elastic case)

F_y	33,000	36,000	42,000	50,000
b/t	16.6	15.9	14.7	13.5

b) Attaining The Plastic Moment (M_p)

$$\lambda = 0.46 = \sqrt{\frac{F_y}{F_{cr}}} \quad \text{(Fig 17.12)} \qquad F_{cr} = k\,\frac{\pi^2 E_t}{12(1-\mu^2)}\left(\frac{t}{b}\right)^2 \quad \text{(eqn 17.11)}$$

so: $$\frac{b}{t} \le \frac{\pi}{\sqrt{F_{cr}}}\sqrt{\frac{k E_t}{12(1-\mu^2)}} \le .46\pi\sqrt{\frac{29{,}000{,}000}{12 \times .91}}\sqrt{\frac{k}{F_y}}$$

$$\frac{b}{t} \le \frac{2354\sqrt{k}}{\sqrt{F_y'}}$$

$k = 0.425$ (p. 538) $\qquad \boxed{\frac{b}{t} \le \frac{1535}{\sqrt{F_y'}}}$ (plastic case)

F_y	33,000	36,000	42,000	50,000
b/t	8.4	8.1	7.5	6.9

$\frac{b}{t} = \frac{.7\pi}{\sqrt{F_y}}\sqrt{\frac{kE}{12(1-\mu^2)}} = \frac{.7\pi}{\sqrt{F_y}}\sqrt{\frac{.7 \times 29{,}000{,}000}{12 \times .91}} = \frac{94.5}{\sqrt{F_y}} \approx \frac{95}{\sqrt{F_y}}$ (per AISC)

$\frac{b}{t} = \frac{.46\pi}{\sqrt{F_y}}\sqrt{\frac{.425 \times 29{,}000{,}000}{12 \times .91}} = \frac{42.6}{\sqrt{F_y}} \approx \frac{52}{\sqrt{F_y}}$ (per AISC) ref 2, p. 303

ie. continuous flange

Local Buckling Provisions For Skinplates

a) Attaining The Yield Moment (M_y):

$$\lambda = 0.7 = \sqrt{\frac{F_y}{F_{cr}}} \qquad \frac{b}{t} \le \frac{3600\sqrt{k}}{\sqrt{F_y}} \text{ (psi)} \qquad \text{ref 1 (eqns 17.21, 17.22)}$$

$k = 5.0$ (para 17.4.2.4) $\qquad \boxed{\frac{b}{t} \le \frac{8050}{\sqrt{F_y}}}$

or: $$\frac{b}{t} \le \frac{\lambda\pi}{\sqrt{F_y}}\sqrt{\frac{k\,E}{12(1-\mu^2)}} \le \frac{.7\pi}{\sqrt{F_y}}\sqrt{\frac{5\times 29{,}000}{12\times .91}} \le \frac{253.4}{\sqrt{F_y}} \text{ (ksi)} \qquad \boxed{\frac{b}{t} \le \frac{253.4}{\sqrt{F_y}}}$$

or: $$\frac{b}{t} \le \lambda\pi\sqrt{\frac{k}{12(1-\mu^2)}}\sqrt{\frac{E}{F_y}} = .7\pi\sqrt{\frac{5}{12\times .91}}\sqrt{\frac{E}{F_y}} \qquad \boxed{\frac{b}{t} \le 1.49\sqrt{\frac{E}{F_y}}}$$

and $F_b \le 0.5\,F_y$ per EM 1110-2-2702

b) Attaining The Plastic Moment (M_p):

$$\lambda = 0.58 = \sqrt{\frac{F_y}{F_{cr}}} \qquad F_{cr} = k\,\frac{\pi^2 E_t}{12(1-\mu^2)}\left(\frac{t}{b}\right)^2 \qquad \text{ref 1 (Fig 17.12, eqn 17.12)}$$

$k = 4.0$ (p. 538) $\qquad \frac{b}{t} = \frac{\lambda\pi}{\sqrt{F_y}}\sqrt{\frac{k\,E_t}{12(1-\mu^2)}}$

$$\frac{b}{t} \le \frac{.58\pi}{\sqrt{F_y}}\sqrt{\frac{4\times 29{,}000{,}000}{12(.91)}} = \frac{5938}{\sqrt{F_y}} \text{ (psi)} \qquad \boxed{\frac{b}{t} \le \frac{5938}{\sqrt{F_y}}}$$

$$\frac{b}{t} \le \frac{.58\pi}{\sqrt{F_y}}\sqrt{\frac{4\times 29{,}000}{12\times .91}} = \frac{187.6}{\sqrt{F_y}} \qquad \boxed{\frac{b}{t} \le \frac{188}{\sqrt{F_y}}}$$

$$\frac{b}{t} \le .58\pi\sqrt{\frac{4}{12\times .91}}\sqrt{\frac{E}{F_y}} \le 1.10\sqrt{\frac{E}{F_y}} \qquad \boxed{\frac{b}{t} \le 1.1\sqrt{\frac{E}{F_y}}}$$

and $F_b \le 0.55\,F_y$

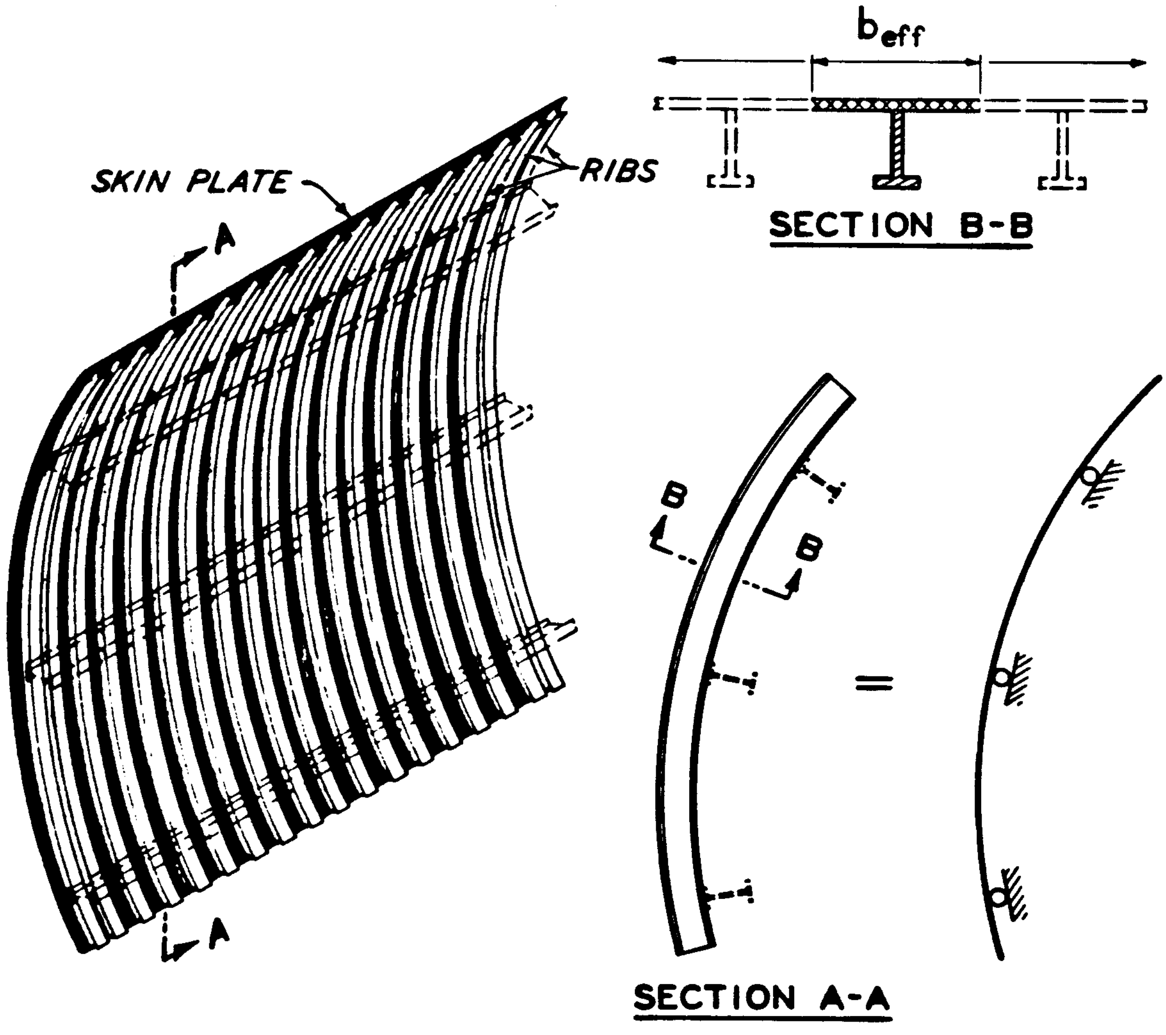
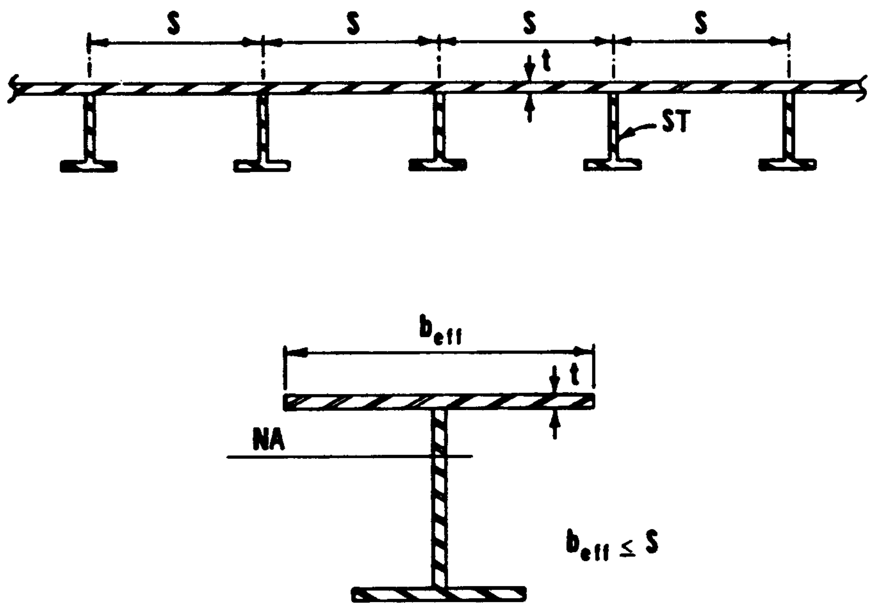


Figure B-24. Composite rib action



$$b_{eff} \le 1.5\, t \sqrt{\frac{E}{F_y}} \qquad \text{(FOR } f \le 0.5\, F_y\text{)}$$

$$b_{eff} \le 1.1\, t \sqrt{\frac{E}{F_y}} \qquad \text{(FOR } f = 0.55\, F_y\text{)}$$

Figure B-25. EM 1110-2-2702 criterion for effective skin plate width

THE BASIC EQUATION FOR PLATE BUCKLING STRESS IS:

$$F_{cr} = k \frac{\pi^2 E_t}{12(1 - \mu^2)} \left(\frac{t}{b}\right)^2$$

PER STRUCTURAL STEEL DESIGN BY BEEDLE ET AL., P. 525

TO ENSURE THAT YIELDING WILL OCCUR PRIOR TO BUCKLING THE FOLLOWING SAFETY FACTOR (F_s) IS REQUIRED

$$F_s = \frac{F_{cr}}{F_y} \text{ OR } \lambda^2 = \frac{1}{F_s} = \frac{F_y}{F_{cr}}$$

SO:

$$\lambda = \sqrt{\frac{F_y}{F_{cr}}} = \frac{b}{t} \sqrt{\frac{F_y}{E_t} \cdot \frac{12(1 - \mu^2)}{k\pi^2}}$$

USING:

μ = POISSON'S RATIO = 0.3

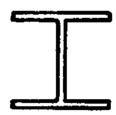
k = A PLATE BUCKLING COEFFICIENT DEPENDENT ON THE TYPE OF SUPPORTS

E_t = E = MODULUS OF ELASTICITY

Figure B-26. Basic equation for stability of thin plates

ACCORDING TO EXPERIMENTAL RESULTS BY BEEDLE:

FOR W SHAPES



CANTILEVER FLANGES

$$\frac{b}{t} \leq \lambda \pi \sqrt{\frac{k}{12(1 - \mu^2)} \cdot \frac{E}{F_y}}$$

FOR $f_y < 0.6\ F_y$ (PER AISC)

$\lambda = 0.7$ (BEEDLE, P. 533)

$k = 0.7$ (BEEDLE, P. 534)

$$\frac{b}{t} = 0.7\ \pi \sqrt{\frac{0.7 \times 29{,}000}{12(1 - 0.3^2)\ F_y}}$$

$$\frac{b}{t} = \frac{95}{F_y}$$

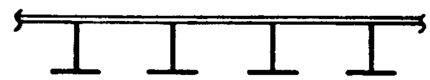
FOR $f_y = 0.66\ F_y$ (PER AISC)

$\lambda = 0.46$ (BEEDLE, P. 538)

$k = 0.425$ (BEEDLE, P. 526)

$$\frac{b}{t} = \frac{52.2}{F_y}$$

FOR SKINPLATES



CONTINUOUS UPSTREAM FLANGE

$$\frac{b}{t} < \lambda \pi \sqrt{\frac{k}{12(1 - \mu^2)} \cdot \frac{E}{F_y}}$$

FOR $M < M_y$ OR $f_y < 0.5\ F_y$:

$\lambda = 0.7$ (BEEDLE, P. 533)

$k = 5.0$ (BEEDLE, P. 534-6)

$$\frac{b}{t} = 0.7\ \pi \sqrt{\frac{5}{12(0.91)} \cdot \frac{E}{F_y}}$$

$$\frac{b}{t} = 1.5 \sqrt{\frac{E}{F_y}}$$

FOR $M < M_p$ OR $f_y < 0.55\ F_y$

$\lambda = 0.58$ (BEEDLE, P. 538)

$k = 4.0$ (BEEDLE, P. 538)

$$\frac{b}{t} = 1.1 \sqrt{\frac{E}{F_y}}$$

Figure B-27. Comparison of AISC and EM width-thickness ratios